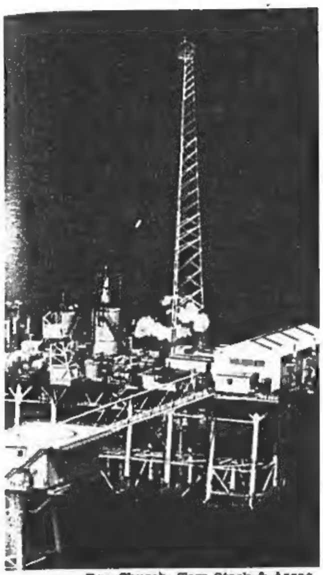

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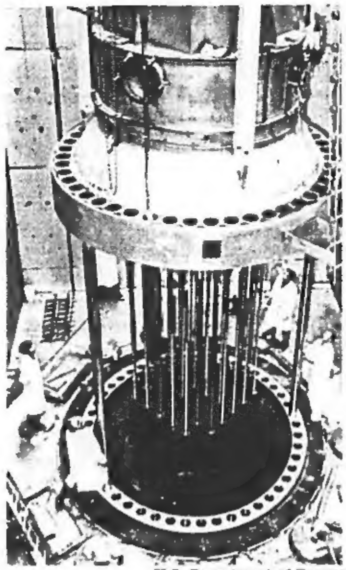


U.S. Department of Energy

Georg Gerster, Rapho Guillumette

Sources of Energy include petroleum, nuclear energy, and sunlight. Offshore wells, *left,* tap oil deposits that lie underwater. Nuclear reactors, *center,* produce power from the splitting of atomic nuclei. Solar furnaces, *right,* use mirrors to collect the rays of the sun.

ENERGY SUPPLY

ENERGY SUPPLY is the total quantity of usable energy available to people. We use forms of energy to do work, to provide warmth, and to move people and goods from place to place. Electrical energy operates vacuum cleaners, washing machines, and other appliances. Heat energy cooks food on stoves and warms air in furnaces. Mechanical energy turns the wheels of cars.

About 95 per cent of the energy we use comes from coal, oil, and natural gas. These substances are called *fossil fuels* because they developed from the fossilized remains of prehistoric plants and animals.

The earth has only a limited supply of fossil fuels. The amount of fossil fuel burned by people has nearly doubled every 20 years since 1900. Someday, the supply will run out. Scientists are seeking new sources of energy to replace shrinking fossil fuel reserves.

Sources of Energy

The chief sources of energy throughout the world are, in order of importance, fossil fuels, water power, and nuclear energy. In addition, solar energy, wind power, tidal energy, and geothermal power provide small amounts of energy. Energy sources in the experimental stage include magnetohydrodynamic (MHD) generators, fuel cells, solid wastes, and hydrogen.

Fossil Fuels include, in order of the amount used worldwide, petroleum, coal, and natural gas. Bituminous sands and oil shale form important resources for the future. Many people also classify wood as one of the fossil fuels.

Petroleum furnishes about 45 per cent of the energy used in the world and in the United States. It provides most of the energy used for transportation and heats millions of homes as well.

Petroleum is easier to get out of the ground than coal is, and pipelines carry it cheaply over long distances. Like coal, oil contains impurities that cause air pollution. But refineries can remove many of these pollutants when they process the petroleum.

Coal provides about 30 per cent of all the energy used in the world. It furnishes about 20 per cent of the energy used in the United States. The major uses of coal include the production of electricity and of steel. Coal also provides heat and power for many other industries. In Europe and Asia, coal heats countless homes.

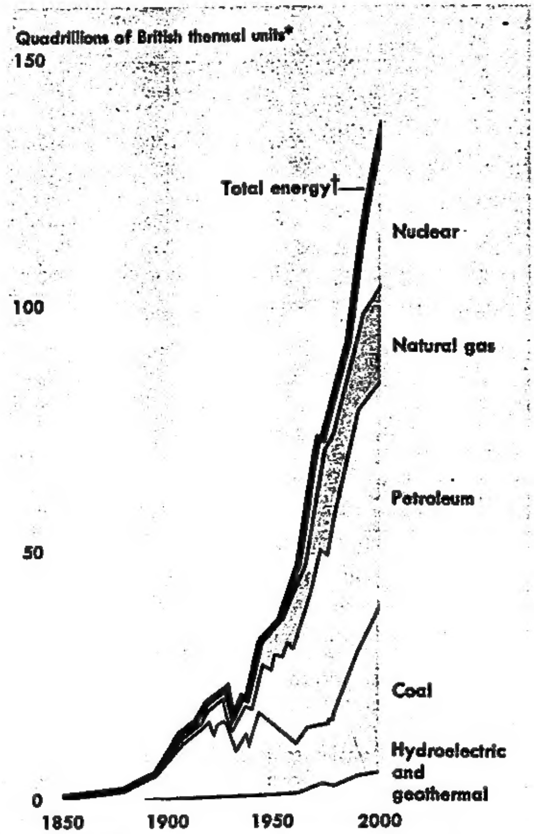
The mining, transportation, and burning of coal all involve serious problems. Miners working deep in the earth face the danger of explosions and falling rock and of black lung disease, caused by breathing coal dust. Strip mining destroys trees and makes huge gashes in the landscape. After coal has been mined, it is expensive to haul. And when burned, it releases sulfur and other impurities that pollute the air.

Chemists have developed various methods of turning coal into a gas or a liquid. Gasified coal can serve as a substitute for natural gas. Liquefied coal can be used to make artificial gasoline. Both gasification and liquefaction convert "dirty" coal into a clean fuel that has a low sulfur content. Both processes also produce fuels that can flow through pipelines and replace natural fuels. But either type of conversion is expensive and requires huge quantities of coal.

Ralph E. Lapp, the contributor of this article, is Senior Member of Quadri-Science, Inc., and the author of The Logarithmic Century.

Sources of U.S. Energy

This graph shows how energy sources have changed since 1850. In the 1950's, petroleum replaced coal as the most important fuel. By the year 2000, nuclear energy may supply a fifth of U.S. power.



*One British thermal unit (BTU) equals 1,055 joules.
†Total for year 2000 includes 6.9 quadrillion BTU's from oil shale, solar energy, and biomass (burning or gasification of wood and wastes).

Sources: *Annual Report to Congress, 1977*, Energy Information Administration, U.S. Department of Energy, April 1978; *Historical Statistics of the United States, Colonial Times to 1970*, U.S. Bureau of the Census, September 1975; *Monthly Energy Review*, September 1978, U.S. Department of Energy.

Natural Gas accounts for about 20 per cent of the energy used in the world and about 25 per cent of that used in the United States. Millions of people use gas to heat their homes, cook their meals, and dry their laundry. Many industries use gas for heat and power.

Natural gas is the cleanest and most convenient fossil fuel. It can easily be transported through pipelines, and it causes almost no air pollution.

Bituminous Sands, also known as *oil sands* or *tar sands*, someday may become a major source of oil. But the process of removing the oil from these sands costs more than the normal production of petroleum.

Oil Shale is a type of rock that can be processed to yield petroleum. But oil obtained from shale costs more than that pumped from the earth. In addition, oil-shale mining tears up large areas of the countryside and produces huge piles of waste rock.

Wood once served as the chief fuel. It still furnishes a small percentage of the energy used in the world. But wood's importance as a source of energy will probably decrease in the future.

Water Power furnishes about 2 per cent of the world's energy. It provides 4 per cent of the energy used in the United States. Water costs nothing and cannot be used up, and it supplies energy without pollution. But most water power projects require a dam or other expensive structure. Also, a water power plant can operate only where water flows from a higher place to a lower one. Many suitable locations already have power plants.

Nuclear Energy provides about 1 per cent of the energy used in the world and about 4 per cent of the energy used in the United States. Nuclear energy comes from *fission*, the splitting of the atoms of certain elements, especially uranium. Fission *reactors* (devices in which controlled atomic reactions take place) power several ships and generate some electricity. By the year 2000, nuclear energy may furnish about 20 per cent of the power in the United States.

Eventually, physicists expect to control the power of *fusion*, the combining of atomic nuclei. Fusion produces the heat and light of the sun and stars—and the explosive force of the hydrogen bomb.

Nuclear Fission creates huge amounts of energy from small amounts of fuel. Nuclear plants also produce electricity without the air pollution caused by burning.

But fission has several disadvantages as a source of energy. Experts predict that the supply of high-quality uranium will last only until the end of the century. Also, fission plants produce more waste heat than do plants that burn ordinary fuel. Unless nuclear plants have expensive cooling devices, their waste heat creates *thermal* (heat) *pollution* that may damage the environment. They also produce tons of radioactive wastes yearly. In addition, nuclear power plants present the danger of accidental discharges of radioactivity.

A *breeder reactor* could provide immense quantities of energy, exceeding those from coal. This special type of reactor produces more fuel than it uses to produce energy. Such surplus fissionable material can be used by other nuclear reactors. A breeder reactor would generate less unused heat than an ordinary reactor. Scientists expect to develop efficient breeder reactors for wide-scale commercial use by the early 1990's.

Nuclear Fusion occurs only at very high temperatures. For this reason, such a reaction is also called a *thermonuclear reaction*. Some scientists believe controlled fusion will be achieved by the year 2000. This accomplishment might solve the world's energy problems for millions of years, if fusion proves to be economical.

A fusion reactor would use *deuterium*, a form of hydrogen, for fuel. The oceans contain enough deuterium to provide all the energy people may ever need. In addition, fusion would create little danger of explosion or radiation. The problem of waste disposal would not arise because most products of fusion are not radioactive.

Solar Energy is used throughout the world to perform various small jobs. For example, simple devices called *flat-plate collectors* heat buildings and water by absorbing the sun's heat. Devices called *solar cells* or *photovoltaic cells* convert light into electricity.

Solar energy could provide a clean and almost unlimited supply of power. But solar energy is spread so thinly that large-scale use of the sun's power would require a huge land area. In addition, darkness and bad weather interrupt the supply of sunlight.

Wind Power turns windmills and propels sailboats. Airplanes use the power of a high-altitude wind called the *jet stream*. Wind itself costs nothing and creates no pollution. But wind power is practical only in areas that have strong, steady winds.

Tidal Energy can be used wherever there are high tides in a bay that can be closed by a dam. During high tide, the bay fills with water. During low tide, the level of the ocean drops below the level of water stored behind the dam. The stored water is then released. As the water falls, it drives turbines that generate electricity. The world's first tidal power plant began to operate in 1966 in France. The chief disadvantage of tidal power is that it can produce electricity only at certain times and for short periods. In addition, plants can be built in few places.

Geothermal Power is generated wherever water comes into contact with heated underground rocks and turns into steam. Power companies drill into areas where underground steam is trapped and direct it into the blades of steam turbines. In areas where underground steam does not exist naturally, engineers can create it by injecting water into hot rock. Geothermal power plants do not burn anything, and so no smoke pollutes the air. Some of these plants produce electricity more cheaply than do ordinary power plants. Several countries, including Italy, Japan, and the United States, had developed geothermal power plants by the mid-1970's.

Magnetohydrodynamic (MHD) Generators convert fuel directly into electricity. An MHD generator burns coal or other fuel at high temperatures to produce a hot *ionized* (electrified) gas. The gas shoots through a magnetic field, where it produces an electric current that is drawn off by electrodes. After the gas has passed through the MHD generator, it can drive a turbine to produce more electricity. MHD generators could provide a highly efficient power source, but many technical problems remain to be solved. In the mid-1970's, Russia had the world's only large MHD generator.

Fuel Cells are batterylike devices in which gas or liquid fuels combine chemically to generate electricity. Fuel cells in the Apollo spacecraft produced electricity from a reaction of hydrogen and oxygen. Fuel cells can produce twice as much electricity as ordinary generators can from a given amount of fuel. Nothing burns in fuel cells, so they cause little pollution and lose little energy in waste heat. But they are expensive to make.

Solid Wastes can also provide energy. Various cities throughout the world produce electric power by burning trash. Another process, called *bioconversion*, uses plant and animal wastes to produce such fuels as methanol, natural gas, and oil. For example, one bioconversion method used in the United States extracts oil from waste wood chips by means of intense heat and pressure.

Hydrogen could someday replace both gas and oil as a fuel. It burns easily, giving off huge amounts of heat and one harmless by-product, water. Chilled to liquid form, hydrogen could flow through pipelines. It might serve as a lightweight, nonpolluting fuel for aircraft and automobiles. Hydrogen can be extracted from ocean water by running an electric current through the water. But this process, called *electrolysis*, requires enormous quantities of electricity.

History

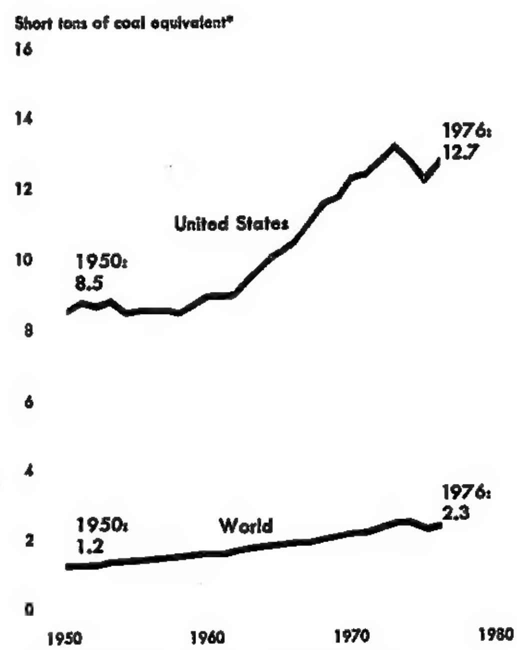
Early Days. Human beings learned to make fire about 500,000 B.C. Until then, their only source of energy had been their own strength. With the heat energy released by burning wood, people warmed themselves, cooked food, and hardened pottery. About 3200 B.C., the Egyptians invented sails and used the wind to propel their boats. Water wheels, developed in ancient times, harnessed the power of falling water.

Until the late 1700's, wood ranked as the most important fuel. People used so much timber that it began to grow scarce, and coal gradually took its place. The growing demand for coal brought a search for better mining methods, including ways to keep mine shafts from flooding. In 1698, an English inventor named Thomas Savery patented an improved pump to drain mines. Savery's pump was powered by the first practical steam engine. People now had a device that could change heat into mechanical energy to do work.

The Industrial Revolution. The steam engine became the chief source of power for industry and transporta-

Energy Use Per Person

The graph below shows how the level of energy use per person has risen since 1950. Energy consumption per person is nearly six times as high in the United States as in the entire world.

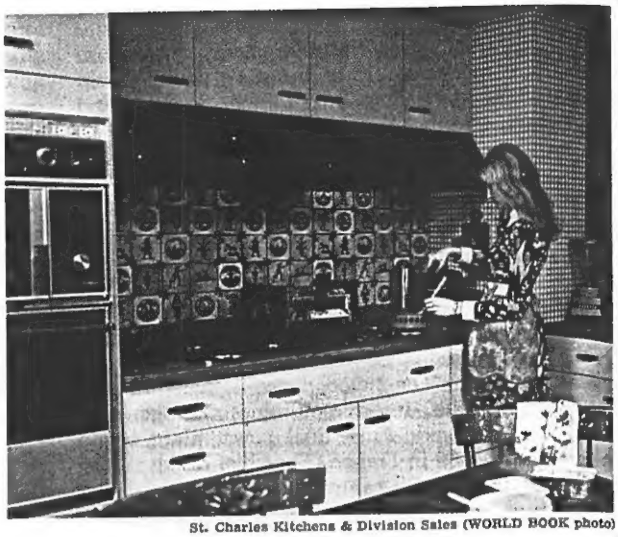


*One short ton of coal equals 0.9071847 metric ton.

Source: *Statistical Yearbooks*, 1960-1977, United Nations.

Bettmann Archive

Energy Use Has Jumped Since the 1800's. A kitchen of the 1870's, *above,* had few energy-consuming devices other than a coal-burning stove. A modern kitchen, *right,* includes such electric appliances as blenders and percolators, as well as an electric range.



St. Charles Kitchens & Division Sales (WORLD BOOK photo)

tion during the Industrial Revolution. People's use of energy increased tremendously during this period, from the 1700's to the mid-1800's. Power-driven machinery largely replaced hand labor, and steamboats replaced sailing ships. New uses of energy made work easier and more productive, and increased production brought greater wealth. This prosperity helped bring about a growth in population, and so there were more people to consume energy. At the same time, people could afford more energy-consuming comforts and conveniences.

During the 1800's, inventors learned about many new sources of energy—and ways to use it. In 1831, the English physicist Michael Faraday discovered a way to turn mechanical energy into electricity. He found that a moving magnet produced electric current in a coil of wire. Operating on this principle, called *electromagnetic induction*, generators could produce electricity from the turning of a water wheel or a steam turbine.

In 1860, Jean Joseph Étienne Lenoir, a French inventor, built one of the first workable internal-combustion engines. These engines produced power from the explosion of a mixture of air and flammable vapors. Gasoline, which is made from petroleum, proved to be the most convenient fuel because it easily turned into vapor. In 1885, Karl Benz, a German engineer, built one of the first gasoline automobiles. The demand for petroleum soared as automobiles came into use.

The 1900's. Since 1900, the consumption of energy has almost doubled every 20 years. Causes of growth in the use of energy include (1) the population increase, (2) the growth of the labor force, (3) increased wealth, (4) energy-using inventions, (5) products that take large amounts of energy to be manufactured, and (6) nonfuel uses of fossil fuels.

The population of just the United States increased about 35 per cent from 1950 to 1970. But during that same period, the use of energy doubled. More people acquired jobs, and energy was needed to transport them to work. At their place of work, they needed power to run various machines and to provide heat and light. As people earned more money, they could afford to buy such energy-using conveniences as air conditioners and cars. At the same time, countless new appliances, including electric can openers and electric toothbrushes, consumed power. People also used more of such materials as aluminum and plastic, which required huge amounts of energy to manufacture. Finally, many new products used coal or petroleum as a raw material. Nonfuel items made from fuels included detergents, fabrics, fertilizers, plastics, and synthetic rubber.

The United States has large stocks of coal and oil. These abundant resources have fueled industrial expansion and helped provide one of the world's highest standards of living. Today, the United States has only about 5 per cent of the world's population. But the nation consumes about 30 per cent of the world's energy. Energy use by the United States has increased at a rate of more than 4 per cent nearly every year since 1947.

A person in a developing country uses only about a sixteenth as much energy as a person in one of the developed countries. Europe, Japan, and the United States consume more than three-fourths of the world's energy. But they have about one-fourth of its people.

Developing countries can do little to limit their energy consumption without sacrificing important goals. They need more factories, farm machinery, and transportation facilities, all of which require energy to operate. Their people also want more central heating, electric lighting, and other comforts that use energy.

Problems

The use of energy creates serious problems. They include (1) depletion of fuel reserves, (2) environmental pollution, and (3) political and economic effects.

Depletion of Fuel Reserves. The people of the world have rapidly used up sources of energy that had accumulated for millions of years. The period of greatest fossil-fuel formation began about 345 million years ago. For about 70 million years, huge quantities of dead trees and other plants were buried in the earth through natural processes. Time, heat, and pressure slowly changed this buried plant material into coal. Petroleum and

natural gas were both formed in much the same way from the remains of ocean plants and animals. The formation of fossil fuels is still going on—but people burn the fuels thousands of times faster than they form.

The rapid growth of energy use threatens to exhaust the world's supply. Petroleum may become the first fuel to give out—growing scarce in the early 2000's. Natural gas is also being used up quickly. In the mid-1970's, gas experts predicted that the earth's reserves would last only about 40 years. When people have removed all the oil and natural gas from the earth, they will have used up the "easy energy" supplied by nature. After that, they will have to use such solid fuels as coal and oil shale. These substances are more difficult to remove from the earth. Coal, the most plentiful fossil fuel, will last about 1,500 years. Eventually, people will have to find different sources of energy altogether.

Environmental Pollution. The production, transportation, and use of fossil fuels all create environmental problems. Deep coal mines endanger workers, and strip mining exposes large areas of land to erosion. The drilling of offshore oil fields and the shipment of petroleum by tankers sometimes produce oil spills that pollute the ocean, damage beaches, and kill wildlife. Hot oil flowing through the Trans-Alaska Pipeline may cause thermal pollution that will damage the Arctic environment. Motor-vehicle fuels produce about half of all air pollution. When burned, coal and fuel oil give off sulfur dioxide, a harmful gas. But when sulfur dioxide mixes with the moisture in the air, it forms sulfuric acid, which eats away metal and stone—and human lungs. See ENVIRONMENTAL POLLUTION.

Even the cleanest fossil fuel produces carbon dioxide when it burns. Carbon dioxide is a harmless gas. But a build-up of this gas in the atmosphere may cause a phenomenon called the *greenhouse effect.* Carbon dioxide, like glass in a greenhouse, allows sunlight to warm the earth but prevents heat from escaping back into space. The greenhouse effect could permanently raise temperatures on the earth, partially melting the polar icecaps and causing floods.

All other sources of energy also cause some environmental damage. Nuclear power plants create thermal pollution and radioactive wastes. Geothermal plants produce waste heat and sometimes offensive odors. Tidal power and solar sea power may disturb marine life by changing conditions in the oceans. Any use of energy, no matter how clean the source, gives off waste heat. If the use of energy continues to grow, the heat released will alter the environment of many cities.

Political and Economic Effects. More than 60 per cent of the world's oil reserves lie in the Middle East and North Africa. Many industrialized nations rely on oil from Arab countries to fuel their economy. Such countries as France, Germany, Great Britain, and Japan import most of their petroleum from the Middle East.

The reliance by industrialized nations on Arab oil gives the Middle Eastern nations considerable power. For example, the Arab governments can exert severe political pressure with an oil *embargo.* In 1973, a number of Arab nations stopped or reduced oil shipments to many Western nations. The Arab governments imposed the embargoes in protest against Western support of Israel. Nations that have backed Israel in its conflicts with the Arab nations may become more friendly toward the Arabs—because of the question of Arab oil.

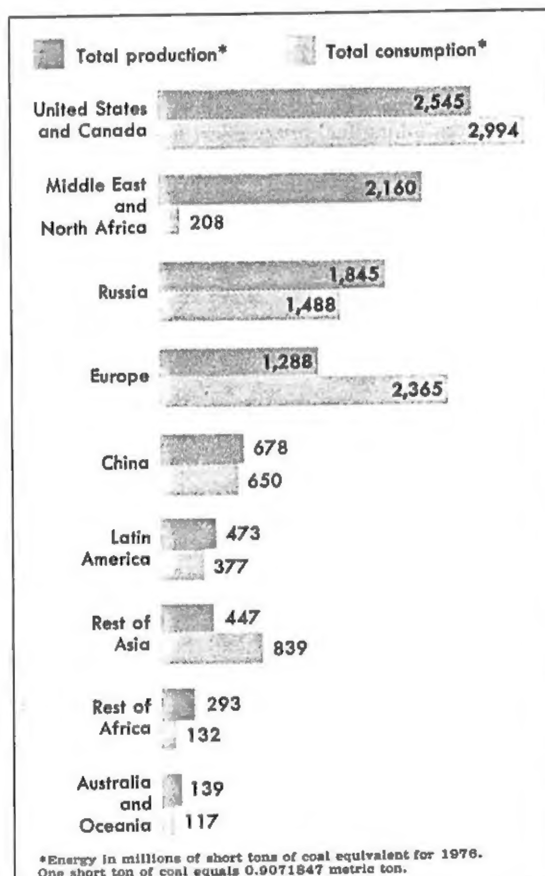
In addition, many nations that buy large amounts of oil from Arab countries do not sell them anything in return. These oil-buying nations may develop a *balance-of-payments deficit*—that is, they import more goods, services, and money than they export. A large balance-of-payments deficit can weaken a nation's economy.

Some people fear that if a nation's use of energy stops growing, a depression will result. They point out that fuel shortages during the mid-1970's resulted in increased unemployment and decreased production. Other people believe industrialized nations waste so much energy that they could save large amounts of it without damaging their economic growth.

As fuels become scarce, their price goes up. Many people then call for price controls on these sources of

World Energy Production and Consumption

This graph shows the amount of energy produced and used by various regions of the world. Europe does not produce enough to meet its needs, but the oil-rich Middle East has energy to spare.



Source: *World Energy Supplies, 1972-1976*, United Nations.

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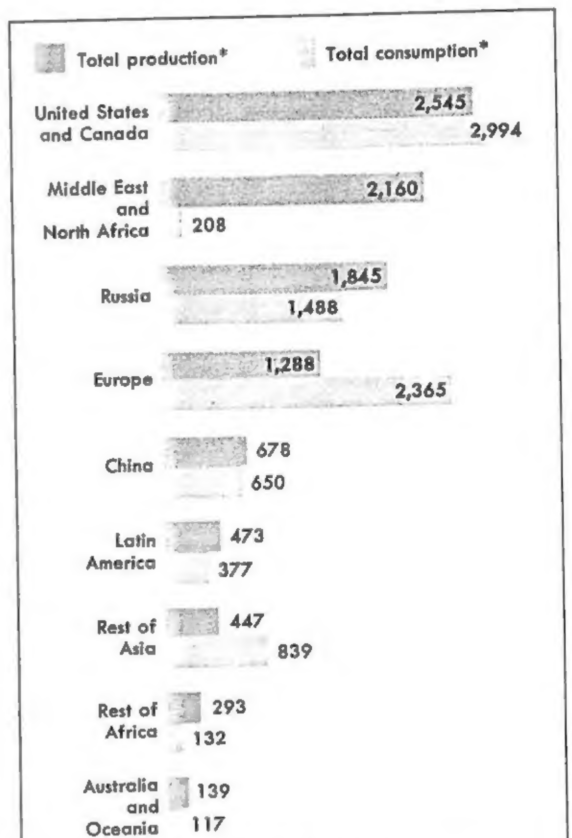


*Energy in millions of short tons of coal equivalent for 1976. One short ton of coal equals 0.9071847 metric ton.

Source: *World Energy Supplies, 1972-1976*, United Nations.

energy. But large numbers of economists believe rising prices encourage energy producers to broaden their explorations and dig deeper for fuels. Low-grade deposits may become profitable to mine, and scientists will investigate new sources of energy. These economists also say that higher fuel prices cause people to use energy more carefully.

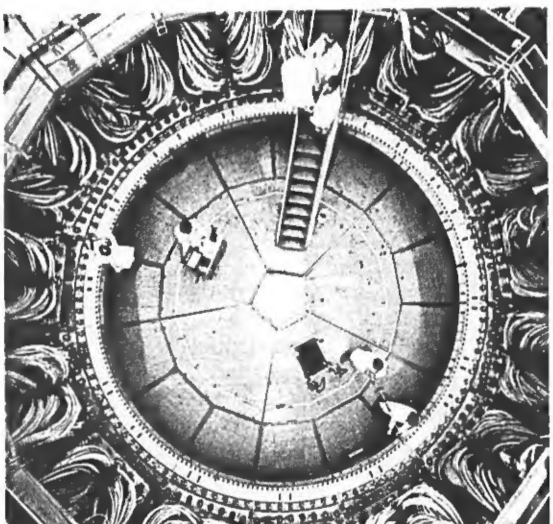
Nevertheless, the increasing cost of energy can be a serious handicap to developing nations. If energy costs more, many of these countries cannot afford the energy they need to become more industrialized and so strengthen their economy.

Challenges

Challenges presented by the earth's diminishing energy supply include (1) developing new sources of energy, (2) improving the efficiency of power generation, and (3) energy conservation.

Developing New Energy Sources. Scientists have many problems to solve before new sources of energy become practical. Nuclear physicists have not yet produced a reliable fast breeder or controlled nuclear fusion. To turn solar energy into a practical power source, scientists must find better ways to gather, concentrate, and store it. Fuel cells and solar cells have provided power for space programs, but they cost too much for individuals to use. Hydrogen could replace fossil fuels if power companies could produce it cheaply.

Improving Efficiency. Even if new sources of energy appear quickly, people would have to rely on ordinary fuels for many years. During this period, engineers could make the shrinking fuel reserves last longer by designing more efficient power plants and engines. An automobile engine, for example, actually uses only about 20 per cent of the energy available in gasoline. The rest goes into wasted heat. Even the most efficient power plants turn only 40 per cent of their fuel into electricity. A new type of plant, the combined gas and steam plant, may boost consumption efficiency to 60 per cent. In an ordinary gas-turbine system, hot gas from burning fuel turns a turbine and then is thrown away. But in a combined plant, this gas drives a turbine and then makes steam to produce additional electricity. The United States wastes about half the fuel that it burns. Greater efficiency would not only save fuel but also would reduce thermal pollution.



Los Alamos Scientific Laboratory

An Experimental Fusion Device called *Scyllac* has been developed by the Los Alamos Scientific Laboratory. Nuclear fusion may someday provide an almost unlimited source of energy.

Energy Conservation. At the same time, conservation can do much to relieve the strain on the earth's energy supply. Better insulation of buildings could save up to half the fuel used for heating and air conditioning. More people could travel by bus and train, rather than by car. Those who must drive could buy smaller cars and form car pools. More families could use fluorescent lights, which produce three times more light per unit of electricity than incandescent lights do. Businesses and families could lower their thermostats in winter and raise them in summer and turn off unnecessary lights. These and other conservation actions could provide the time needed for research that might lead to new sources of energy.

RALPH E. LAPP

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Magnetohydrodynamics
Nuclear Energy
Nuclear Reactor
Oil Shale
Petroleum
Power
Solar Energy
Turbine
Water Power
Windmill

Outline

I. Sources of Energy
- A. Fossil Fuels
- B. Water Power
- C. Nuclear Energy
- D. Solar Energy
- E. Wind Power
- F. Tidal Energy
- G. Geothermal Power
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II. History

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- A. Depletion of Fuel Reserves
- B. Environmental Pollution
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IV. Challenges
- A. Developing New Energy Sources
- B. Improving Efficiency
- C. Energy Conservation

Questions

What are fossil fuels?
What was the first source of energy used by human beings other than their own strength?
What regions of the world have more than 60 per cent of the world's oil reserves?
How much of the fuel burned in the United States is wasted?
Why is sulfur dioxide such a harmful pollutant?
What is the difference between fission and fusion?
What substance ranked as the most important fuel throughout most of history?
What is the most abundant fossil fuel?
What steps can families take to conserve energy?
What is the *greenhouse effect?*